APPENDIX 2

Correspondence

C O P Y

Abstract from:

AIR COORDINATING COMMITTEE
NEW YORK SUBCOMMITTEE ON AIRSPACE
RULES OF THE AIR AND AIR TRAFFIC CONTROL
385 Madison Avenue
New York 17, N. Y.

20 March 1947

N. Y. Meeting No. 12

PROBLEM:

1. The Secretary of the Subcommittee presented a request from the War Department member in behalf of New York University for approval to release free balloons from Allentown, Pa. and Lakehurst, N. J.

DISCUSSION

2. The subject project is broken down into two phases as described below:

A. PHASE I.

(1) The type balloon to be used in this phase of the project will be 6 ft. in diameter, hydrogen filled, encompassed by a nylon shroud with black and white panels 24" wide. Radio instruments weighing approximately 3 lbs. will be suspended approximately 50 ft. below the balloon and equipped with parachute device so that upon separation from the balloon, the attached equipment will float down towards the earth rather than become a freely falling body.

(2) It is anticipated that two flights will be required in this phase of operation, the release to be made during weather conditions in which the sky is free of clouds and the visibility at least three miles at all altitudes up to 20,000 feet., within a four hour cruising radius from Allentown, Pa.

(3) The balloon, during these flights, shall be conveyed by suitable aircraft to maintain air-ground communications on the balloon trajectory and equipped to effect destruction of the balloon at the termination of four hours flight or at such time that the balloon may become hazardous either to aircraft flight operations or the persons or property of others on the surface.

(4) New York University will file a Notice to Airmen at least twelve (12) hours in advance of balloon release and a second notice will be filed at the time of release with the Allentown, Pa. Airways Communications Station.

B. <u>PHASE II.</u>

(1) The type balloon to be used in this phase of the project will be a 15 to 40 ft. diameter plastic balloon, hydrogen filled. Radio equipment weighing approximately 25 lbs., will be suspended approximately 100 ft. below the balloon. The balloon will be towed to high altitude levels (above 20,000 feet) by three auxilliary lifting balloons fastened together with a 4 lb. weight. All equipment attached to the balloon will be equipped with parachute device so that upon separation from the balloon, the attached equipment will float down towards the earth rather than become a freely falling body. Upon attaining the desired altitude, the auxilliary lifting balloons will be released from the main balloon.

(2) It is anticipated that a maximum of ten flights will be required in this phase of operation, 2 to 5 releases to be made from Allentown, Pa. and 2 to 5 releases to be made from Lakehurst, N. J. Release will be made during weather conditions in which the sky is free of clouds and the visibility at least three miles at all altitudes up to 20,000 feet.

(3) The range of flight during this phase of operation will be between 30,000 and 60,000 feet. A period of six hours will be the maximum duration of flight.

(4) New York University will provide an operator for tracking of the balloon during period of flight and will furnish information on its position to the N.Y. Air Traffic Control Center during period of flight.

(5) New York University will file a Notice to Airmen at least twelve (12) hours in advance of balloon release and a second notice will be filed at time of release with either the Allentown, Pa. or Lakehurst, N.J. Communications Stations.

(6) Destruction of the balloon will be predetermined to be effected over water where hazards are not present. Aerial convoy will not be effected during this phase of operation inasmuch as balloon flights will be conducted in excess of 20,000 feet.

3. The War Department member requests that balloon operations along the lines of Phase II be presented to the Washington Subcommittee for clearance with all other Regional Airspace Subcommittees, in consideration of War Department plans to continue the Phase II type of operation from White Sands, New Mexico, upon completion of the 12 proposed releases described herein. The type of balloon releases proposed out of White Sands, N. Mex., will involve flight through other regions.

RECOMMENDED ACTION

4. That the release of free balloons by New York University as described above in Paragraph 2-A (Phase I), Subparagraphs (1) - (4) inclusive, be approved.

5. That the release of free balloons by New York University as described above in Paragraph 2-B (Phase II), Subparagraphs (1) - (6) inclusive, be approved.

6. That the Washington Airspace Subcommittee present the Phase II operation to other Regional Airspace Subcommittees for clearance, in view of War Department plans to continue the Phase II type of operation from White Sands, New Mexico.

April 17, 1947

Mr. C. J. Stock, Secretary
New York Subcommittee on Air Space
385 Madison Avenue
New York 17, N. Y.

Reference: New York Meeting No. 12 Subject No. 26, New York Case #156

Dear Sir:

Receipt of the minutes of the above meeting are acknowledged with thanks. However, on reading them, a discrepancy was noted. We believe the weather conditions agreed upon for Phase 2 operations were not a cloudless sky, but no ceiling under 20,000 ft.

We realize that there might be occasions when the clouds present would not constitute a ceiling. Yet, due to chaotic or unstable sky conditions, our balloons might be considered an unseen hazard to aircraft.

It is therefore requested that we be permitted to fly these rapidly rising, high altitude balloons after obtaining clearance on days when there are no more than scattered clouds in thin layers up to 20,000 ft. and visibility greater than three miles.

This is an important point, as the phenomena which we hope to measure is not a frequent one and our chances to investigate the remote phenomena are markedly reduced if we have to wait for cloudless skies and the phenomena to coincide.

This would have been brought to your attention earlier. However, we are unable, until yesterday, to confirm our impressions with the representatives of the Army Air Forces who were present at the meeting.

Yours very truly,

C. S. Schneider
Research Assistant

CSS:gm

DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION

385 Madison Ave.
New York 17, N. Y.

New York University
College of Engineering
Research Division
University Heights
New York 53, N. Y.

Attention: Mr. C. S. Schneider, Research Assistant

Dear Mr. Schneider:

This is in reply to your letter of April 17th.

It is true that at N.Y. Airspace Subcommittee Meeting #12, we advised you that the Phase II operations would be restricted to weather conditions in which the sky was clear of clouds below 20,000 feet and the visibility at least three miles at all altitudes up to and including 20,000 ft. However, it was indicated that these conditions were subject to concurrence and approval by the Washington Airspace Subcommittee.

In order to expedite final approval of this case, coordination was effected with the Washington Airspace Subcommittee immediately subsequent to our Meeting #12. It was revealed as a result of such coordination that the Washington Committee felt that the ceiling restriction was inadequate in the interests of air safety and required that a cloudless sky condition be specified.

This information was relayed to the members of the N.Y. Airspace Subcommittee and they in turn concurred with this amendment in the interest of air safety. The minutes of New York Meeting #12 were amended accordingly.

Yours very truly,

C. J. Stock
Secretary, N. Y. Airspace Subcommittee

AIR COORDINATING COMMITTEE
FORT WORTH REGIONAL AIRSPACE SUBCOMMITTEE
P. O. BOX 1689
FORT WORTH 1, TEXAS

August 21, 1947

Meeting No. 30

Time:	August 21, 1947 - 10:00 a.m. to 1:30 p.m.
Place:	Regional Office, CAA, Ft. Worth, Texas
Members Present:	L. C. Elliott, Chairman Lt. Col. Hall F. Smith, War Dept. Member Major Williams, War Dept. Alternate Member Perry Hodgden, CAB Member Commander James Douglas Arbes, Navy Dept. Member Tracy Walsh, ATA Coordinator
Secretary:	Paul H. Boatman

EXTRACT COPY

PROBLEM

1. The Secretary of the Subcommittee presented a request received from the New York University through the Department of Commerce Member for approval of releases of free balloons at the White Sands Proving Ground in Phase II operation as outlined in New York Subcommittee Meeting No. 12, dated March 20, 1947.

DISCUSSION

2. It was first thought that balloons would ascend and descend within the confines of the White Sands presently assigned danger area and that no further authorization would be required; however the Subcommittee was advised by the University that balloons have been descending outside of the area in the vicinity of Roswell, New Mexico. It, therefore, appeared that there was a certain amount of hazard to aircraft encountered in the descent of this equipment.

3. The Subcommittee did not have full information on the number of releases anticipated and other pertinent details; however it appeared the chances of collision of aircraft with this equipment was very remote and due to the fact prevailing winds in this area would ordinarily carry the equipment eastward, which would tend to carry it away from heavy travelled already established civil airways, that this activity might not be too objectionable.

4. The Department of Commerce Member stated that he felt it may be necessary to effect some coordination with air traffic in the local El Paso area but that due to the meager information available, this could not be determined without a discussion of methods and procedures with the people who were actually going to do the work.

5. Thw War Department Member stated that he felt it desirable to stipulate that local coordination should be effected with the Commanding Officer at Biggs Field.

(NOTE: At a meeting held in El Paso, Texas, on August 27, 1947, between representatives of the CAA and the New York University, procedures satisfactory to the Commerce Member and the Commanding Officer at Biggs Field were established).

RECOMMENDED ACTION

6. That release of free balloons by the New York University within the confines of the White Sands Proving area be approved provided that:

(a) Local coordination be effected to the satisfaction of the Department of Commerce Member and the Commanding Officer at Biggs Field to assure all precautions are taken to prevent collision of aircraft with this airborne equipment.

COPY

AIR COORDINATING COMMITTEE
FORT WORTH REGIONAL AIRSPACE SUBCOMMITTEE
P. O. BOX 1689
FORT WORTH 1, TEXAS

September 2, 1947

MEMORANDUM

TO: L. C. Elliott
Chairman, Ft. Worth Regional Airspace Subcommittee

Lt. Col. Hall F. Smith, War Dept. Member, Ft. Worth
Regional Airspace Subcommittee

FROM: Secretary, Ft. Worth Regional Airspace Subcommittee

SUBJECT: Procedure for Release of Free Balloons in the White Sands Danger Area

The writer met with Mr. James R. Smith of New York University and Lt. V. D. Thompson of Alamogordo AAF, at El Paso, Texas, on August 27 to discuss procedures to be followed during the descent of free balloons released within the White Sands Danger Area.

Mr. Smith advised that he had met with the Commanding Officer at Biggs Field who had stated he desired no further coordination other than what the Civil Aeronautics Administration might require and that he would write a letter to Mr. Smith to this effect. Mr. Smith will forward this to the Chairman of the Subcommittee for the record.

Mr. Smith outlined their program, which consists for the most part of testing various types of balloons. Their program will probably be of 5 flights per month for the next 6 months, the first flight to be released on Sept. 6, weather permitting. Weather minimums were agreed on as not more than 4/10 of the sky covered or forecasted to be covered within the expected descent area (60 mile radius).

Balloons are tracked by VHF DF stations at Alamogordo and Roswell for the present plus an aircraft. When the balloon descends to 20,000 feet, if not in the clear, positions will be given every hour or so and will be put out as notams on Schedule "A" from the Roswell AAF. This will serve to advise the Army Fields, the airlines, and some itinerant traffic. In any case if the balloon is outside the assigned danger area, notams will be issued when the balloons descend below 15,000 feet.

The balloons are for the most part 15 feet in diameter and plastic. Suspended from the balloon is a 100 foot one thousand pound test nylon line which carries the airborne equipment. Releases are usually made at dawn and the flight terminates in an average of 8 hours time; it may be from 6 to 12 hours duration.

It is believed the notam procedure will serve to advise pilots of this activity effectively enough to provide the desired amount of caution. It is understood the airlines have some instrument flights through this area at 20,000 feet; however these are for the most part at night and to the north of the expected balloon track.

/s/ Paul H. Boatman
PAUL H. BOATMAN
Secretary, Ft. Worth Regional Airspace
Subcommittee

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APPENDIX 3

Flight Forms and Tables

PRESSURE IN STANDARD ATMOSPHERE

(Accurate to .001 mm of Hq, .0001 in. of Hg and .002 of millibar)

Thermal Layer					Isothermal Layer				
Altitude (feet)	Pressure (mm Hq)	Pressure (In. Hq)*	Pressure (mb)	ft.per (mb)	Altitude (feet)	(mm Hq)*	(In.Hq)*	(mb)	ft per (mb)
-5,000	907.809	35.7404	1210.312		35,332	175.899	6.9251	234.513	
-4,000	876.533	34.5091	1168.615		36,000	170.375	6.7077	227.148	
-3,000	846.130	33.3121	1128.081		37,000	162.430	6.3949	216.556	
-2,000	816.582	32.1488	1088.686		38,000	154.854	6.0966	206.455	
-1,000	787.879	31.0188	1050.419		39,000	147.632	5.8123	196.826	
0	760.000	29.9212	1013.250	27	40,000	140.747	5.5412	187.647	110
1,000	732.923	28.8552	977.150		41,000	134.183	5.2828	178.896	
2,000	706.634	27.8202	942.101		42,000	127.925	5.0364	170.553	
3,000	681.114	26.8155	908.077		43,000	121.959	4.8015	162.599	
4,000	656.344	25.8403	875.053		44,000	116.271	4.5776	155.015	
5,000	632.308	24.8940	843.008	31	45,000	110.848	4.3641	147.785	140
6,000	608.991	23.9760	811.921		46,000	105.678	4.1605	140.892	
7,000	586.375	23.0856	781.769		47,000	100.750	3.9665	134.322	
8,000	564.444	22.2222	752.530		48,000	96.051	3.7815	128.057	
9,000	543.180	21.3850	724.180		49,000	91.571	3.6052	122.085	
10,000	522.571	20.5736	696.704	36	50,000	87.301	3.4370	116.392	175
11,000	502.600	19.7874	670.078		51,000	83.229	3.2767	110.963	
12,000	483.251	19.0256	644.282		52,000	79.348	3.1239	105.789	
13,000	464.511	18.2878	619.297		53,000	75.647	2.9782	100.854	
14,000	446.362	17.5733	595.100		54,000	72.119	2.8393	96.151	
15,000	428.793	16.8816	571.677	43	55,000	68.755	2.7069	91.666	225
16,000	411.786	16.2120	549.003		56,000	65.549	2.5807	87.391	
17,000	395.332	15.5642	527.066		57,000	62.492	2.4603	83.316	
18,000	379.412	14.9375	505.841		58,000	59.577	2.3455	79.429	
19,000	364.018	14.3314	485.317		59,000	56.799	2.2362	75.726	
20,000	349.132	13.7453	465.471	50	60,000	54.150	2.1319	72.194	285
21,000	334.742	13.1788	446.286		61,000	51.624	2.0324	68.826	
22,000	320.836	12.6313	427.746		62,000	49.217	1.9377	65.617	
23,000	307.403	12.1025	409.837		63,000	46,921	1.8473	62.556	
24,000	294.429	11.5917	392.540		64,000	44,733	1.7611	59.639	
25,000	281.901	11.0984	375.837	60	65,000	42.647	1.6790	56.858	360
26,000	269.808	10.6223	359.714		66,000	40.658	1.6007	54.206	
27,000	258.140	10.1630	344.158		67,000	38.762	1.5261	51.678	
28,000	246.883	9.7198	329.150		68,000	36.954	1.4549	49.268	
29,000	236.027	9.2924	314.677		69,000	35.230	1.3870	46.969	
30,000	225.561	8.8803	300.723	72	70,000	33,587	1.3223	44.779	455
31,000	215.473	8.4832	287.274		71,000	32,021	1.2607	42.691	
32,000	205.754	8.1005	274.316		72,000	30,528	1.2019	40.701	
33,000	196.394	7.7320	261.837		73,000	29,104	1.1458	38.802	
34,000	187.381	7.3772	249.821		74,000	27.746	1.0924	36.992	
35,000	178.705	7.0356	238.254	86	75,000	26,452	1.0414	35.266	580
					76,000	25.219	.9929	33.623	
					77,000	24,043	.9466	32,055	

* Mercury column at 0° C.

PRESSURE IN STANDARD ATMOSPHERE

(Accurate to .001 mm of Hq, .0001 in. of Hg and .002 of millibar)

Isothermal Layer

Altitude (feet)	Pressure (mm Hq)*	Pressure (in.Hq)*	Pressure (mb)	Ft. per (mb)
78,000	22.921	.9024	30.559	
79,000	21.852	.8603	29.134	
80,000	20.833	.8202	27.775	735
81,000	19.862	.7820	26.480	
82,000	18.935	.7455	25.245	
83,000	18.052	.7107	24.067	
84,000	17.210	.6776	22.945	
85,000	16.408	.6460	21.876	935
86,000	15.642	.6158	20.854	
87,000	14.913	.5871	19.882	
88,000	14.217	.5597	18.954	
89,000	13.554	.5336	18.071	
90,000	12.922	.5087	17.228	1190
91,000	12.319	.4850	16.424	
92,000	11.745	.4624	15.659	
93,000	11.197	.4408	14.928	
94,000	10.675	.4203	14.232	
95,000	10.177	.4007	13.568	1510
96,000	9.702	.3820	12.935	
97,000	9.250	.3642	12.332	
98,000	8.819	.3472	11.758	
99,000	8.407	.3310	11.208	
100,000	8.015	.3156	10.686	1920

Table 20. Diameters of Circles with Sides of Squares of Equal Areas

Diameter of circle = 1.12838 × side of square of equal area
Side of square = 0.88623 × diameter of circle of same area

Table 21. Spheres: Diameters, Volumes, Surfaces

Diameters by fractions
Surface = 3.14159 × (diameter)²
Volume = 0.523598 × (diameter)³

Diam.	Volume	Surface
1/32	0.00002	0.003068
1/16	.00013	.012272
3/32	.00043	.027612
1/8	.00102	.049087
5/32	.00200	.076699
3/16	.00345	.110447
7/32	.00548	.150330
1/4	.00818	.196349
9/32	.01165	.248505
5/16	.01598	.306796
11/32	.02127	.371223
3/8	.02761	.441786
13/32	.03511	.518485
7/16	.04385	.601321
15/32	.05393	.690291
1/2	.06545	.785398
9/16	.09319	.994019
5/8	.12783	1.22718
11/16	.17014	1.48489
3/4	.22089	1.76714
13/16	.28085	2.07394
7/8	.35077	2.40528
15/16	.43143	2.76116
1	.52360	3.14159
1/16	.62804	3.54656
1/8	.74551	3.97607
3/16	.87681	4.43013
1/4	1.0227	4.90873
5/16	1.1838	5.41188
3/8	1.3612	5.93957
7/16	1.5553	6.49180
1/2	1.7671	7.06858
9/16	1.9974	7.66990
5/8	2.2468	8.29576
11/16	2.5161	8.94617
3/4	2.8062	9.62112
13/16	3.1177	10.32061
7/8	3.4515	11.04465
15/16	3.8082	11.79323
2	4.1888	12 56636
1/16	4.5939	13.36403
1/8	5.0243	14.18624
3/16	5.4808	15.03300
1/4	5 9641	15.90430
5/16	6.4751	16.80014
3/8	7.0144	17.72053
7/16	7.5828	18.66546

Diam.	Volume	Surface
1/2	8.1812	19.63494
9/16	8.8103	20.62896
5/8	9.4708	21.64752
11/16	10.1635	22.69062
3/4	10.8892	23.75827
13/16	11.6486	24.85047
7/8	12.4426	25.96720
15/16	13.2719	27.10849
3	14.1371	28.27431
1/16	15.0393	29.46468
1/8	15.9789	30.67959
3/16	16.9570	31.91905
1/4	17.9741	33.18?04
5/16	19.0312	34.47159
3/8	20.1289	35.78467
7/16	21.2680	37.12230
1/2	22.4493	38.48448
9/16	23.6735	39.87120
5/8	24.9415	41.28246
11/16	26.2539	42.71826
3/4	27.6116	44.17861
13/16	29.0153	45.66350
7/8	30.4658	47.17294
15/16	31.9639	48.70692
4	33.5103	50.26544
1/8	36.7511	53.45612
1/4	40.1943	56.74497
3/8	43.8462	60.13200
1/2	47.7129	63.61720
5/8	51.8004	67.20057
3/4	56.1150	70.88212
7/8	60.6627	74.66185
5	65.4497	78.53975
1/8	70.4822	82.51582
1/4	75.7663	86.59007
3/8	81.3080	90.76250
1/2	87.1136	95.03310
5/8	93.1892	99.40187
3/4	99.5409	103.86882
7/8	106.175	108.43394
6	113.097	113.0972
1/8	120.314	117.8587
1/4	127.832	122.7184
3/8	135.656	127.6762
1/2	143.793	132.7322
5/8	152.249	137.8863
3/4	161.031	143.1387
7/8	170.144	148.4892

Diam.	Volume	Surface
7	179.594	153.9379
1/8	189.388	159.4848
1/4	199.532	165.1298
3/8	210.031	170.8730
1/2	220.893	176.7144
5/8	232.123	182.6540
3/4	243.727	188.6917
7/8	255.711	194.8277
8	268.082	201.0618
1/8	280.846	207.3940
1/4	294.008	213.8245
3/8	307.576	220.3531
1/2	321.555	226.9799
5/8	335.950	233.7048
3/4	350.770	240.5280
7/8	366.019	247.4493
9	381.703	254.4688
1/8	397.829	261.5865
1/4	414.403	268.8023
3/8	431.431	276.1163
1/2	448.920	283.5285
5/8	466.875	291.0389
3/4	485.302	298.6474
7/8	504.207	306.3541
10	523.598	314.1590
1/8	543.479	322.0621
1/4	563.858	330.0633
3/8	584.739	338.1627
1/2	606.130	346.3603
5/8	628.036	354.6561
3/4	650.464	363.0500
7/8	673.420	371.5421
11	696.909	380.1324
1/8	720.938	388.8208
1/4	745.514	397.6075
3/8	770.641	406.4923
1/2	796.327	415.4753
5/8	822.578	424.5564
3/4	849.399	433.7358
7/8	876.797	443.0133
12	904.777	452.3890
1/4	962.512	471.4348
1/2	1022.65	490.8734
3/4	1085.25	510.7047
13	1150.34	530.9287
1/4	1218.00	551.5454
1/2	1288.25	572.5548
3/4	1361.15	593.9569

Diam.	Volume	Surface
14	1436.75	615.7516
1/4	1515.10	637.9391
1/2	1596.25	660.5193
3/4	1680.25	683.4922
15	1767.14	706.8578
1/4	1856.98	730.6160
1/2	1949.81	754.7670
3/4	2045.69	779.3107
16	2144.66	804.2470
1/4	2246.77	829.5761
1/2	2352.07	855.2979
3/4	2460.61	881.4123
17	2572.44	907.9195
1/4	2687.60	934.8194
1/2	2806.16	962.1119
3/4	2928.15	989.7972
18	3053.62	1017.875
1/4	3182.63	1046.346
1/2	3315.23	1075.209
3/4	3451.45	1104.465
19	3591.36	1134.114
1/4	3735.00	1164.155
1/2	3882.41	1194.589
3/4	4033.66	1225.416
20	4188.78	1256.636
1/4	4347.83	1288.248
1/2	4510.86	1320.253
3/4	4677.91	1352.651
21	4849.04	1385.441
1/4	5024.29	1418.624
1/2	5203.71	1452.200
3/4	5387.36	1486.168
22	5575.27	1520.530
1/4	5767.51	1555.283
1/2	5964.11	1590.430
3/4	6165.13	1625.969
23	6370.62	1661.901
1/4	6580.62	1698.226
1/2	6795.19	1734.943
3/4	7014.37	1772.053
24	7238.22	1809.556
1/4	7466.78	1847.451
1/2	7700.10	1885.739
3/4	7938.23	1924.420
25	8181.22	1963.49
1/4	8429.12	2002.96
1/2	8681.97	2042.82
3/4	8939.84	2083.07

Diam.	Volume	Surface
26	9202.76	2123.71
1/4	9470.78	2164.75
1/2	9743.96	2206.18
3/4	10022.3	2248.00
27	10306.0	2290.22
1/4	10594.9	2332.83
1/2	10889.2	2375.83
3/4	11188.9	2419.22
28	11494.0	2463.01
1/4	11804.7	2507.19
1/2	12120.8	2551.76
3/4	12442.6	2596.72
29	12770.0	2642.08
1/4	13103.1	2687.83
1/2	13442.0	2733.97
3/4	13786.7	2780.50
30	14137.1	2827.43
1/4	14493.5	2874.75
1/2	14855.9	2922.46
3/4	15224.2	2970.57
31	15598.5	3019.07
1/4	15978.9	3067.96
1/2	16365.5	3117.24
3/4	16758.3	3166.92
32	17157.3	3216.99
1/4	17562.5	3267.45
1/2	17974.1	3318.30
3/4	18392.1	3369.55
33	18816.5	3421.19
1/4	19247.4	3473.22
1/2	19684.9	3525.65
3/4	20128.9	3578.47
34	20579.5	3631.68
1/4	21036.8	3685.28
1/2	21500.8	3739.28
35	22449.3	3848.45
1/2	23425.2	3959.19
36	24429.0	4071.50
1/2	25461.1	4185.38
37	26521.8	4300.84
1/2	27611.6	4417.86
38	28730.9	4536.46
1/2	29880.0	4656.62
39	31059.3	4778.36
1/2	32269.3	4901.67
40	33510.3	5026.54
1/2	34782.7	5152.99

Diam.	Volume	Surface
41	36086.9	5281.01
1/2	37423.3	5410.60
42	38792.3	5541.76
1/2	40194.3	5674.50
43	41629.7	5808.80
1/2	43098.9	5944.67
44	44602.2	6082.12
1/2	46140.0	6221.13
45	47712.9	6361.72
1/2	49321.0	6503.88
46	50964.9	6647.60
1/2	52645.0	6792.90
47	54361.5	6939.77
1/2	56115.0	7088.21
48	57905.8	7238.22
1/2	59734.2	7389.81
49	61600.8	7542.96
1/2	63505.8	7697.68
50	65449.8	7853.98
1/2	67432.9	8011.84
51	69455.8	8171.28
1/2	71518.7	8332.28
52	73622.1	8494.86
1/2	75766.3	8659.01
53	77951.7	8824.73
1/2	80178.8	8992.02
54	82447.8	9160.88
1/2	84759.3	9331.31
55	87113.6	9503.31
1/2	89511.1	9676.88
56	91952.2	9852.03
1/2	94437.2	10028.7
57	96966.7	10207.0
1/2	99540.9	10386.9
58	102160	10568.3
1/2	104825	10751.3
59	107536	10935.9
1/2	110293	11122.0
60	113097	11309.7
1/2	115948	11499.0
61	118847	11690
1/2	121793	11882
62	124788	12076
1/2	127832	12272
63	130924	12469
1/2	134066	12668
64	137258	12868
1/2	140500	13070

Diam.	Volume	Surface
65	143793	13273
1/2	147137	13478
66	150532	13685
1/2	153980	13893
67	157479	14103
1/2	161031	14314
68	164636	14527
1/2	168294	14741
69	172007	14957
1/2	175773	15175
70	179594	15394
1/2	183470	15615
71	187401	15837
1/2	191389	16061
72	195432	16286
1/2	199532	16513
73	203689	16742
1/2	207903	16972
74	212174	17204
1/2	216504	17437
75	220893	17672
1/2	225340	17908
76	229847	18146
1/2	234413	18386

Diam.	Volume	Surface
77	239040	18626
1/2	243727	18869
78	248474	19114
1/2	253284	19360
79	258154	19607
1/2	263087	19856
80	268082	20106
1/2	273140	20358
81	278261	20612
1/2	283446	20867
82	288695	21124
1/2	294008	21382
83	299387	21642
1/2	304830	21904
84	310339	22167
1/2	315913	22432
85	321555	22698
1/2	327263	22966
86	333038	23235
1/2	338880	23506
87	344791	23779
1/2	350770	24053
88	356817	24328
1/2	362934	24606

Diam.	Volume	Surface
89	369120	24885
1/2	375377	25165
90	381703	25447
1/2	388100	25730
91	394568	26016
1/2	401108	26302
92	407719	26590
1/2	414403	26880
93	421160	27172
1/2	427989	27464
94	434892	27759
1/2	441869	28055
95	448920	28353
1/2	456045	28652
96	463246	28953
1/2	470522	29255
97	477874	29559
1/2	485302	29865
98	492806	30172
1/2	500388	30481
99	508047	30791
1/2	515783	31103
100	523598	31416

Basic Data for Computation of Molar Volume

ALBUQUERQUE, NEW MEXICO

(Mean Sounding)

January 1943

Altitude (KM)	Temp. (°C)	Pressure (Mb)	Humidity %	Molar Volume ft.^{3}
1.620 (Surface)	+ 3.8	838	45	449
2	3.4	800	46	463
2.5	.6	752	45	486
3	- 2.6	706	48	522
4	- 8.3	622	51	567
5	-14.6	546	50	631
6	-21.2	477	48	704
7	-28.3	416	45	786
8	-35.7	332	39	872
9	-43.0	312	-	983
10	-49.7	269	-	1140
11	-54.7	230	-	1250
12	-57.2	197	-	1450
13	-58.1	168	-	1690
14	-60.2	143	-	1990
15	-61.6	122	-	2320
16	-63.0	104	-	2700
17	-64.3	88	-	3170
18	-65.1	75	-	3700
PHOENIX, ARIZONA				
20	-63	54	-	5410

Basic Data for Computation of Molar Volume

ALBUQUERQUE, NEW MEXICO

(Mean Sounding)

August 1943

Altitude (KM)	Temp. (°C)	Pressure (Mb)	Humidity %	Molar Volume ft.^{3}
1.620 (Surface)	25.2	838	44	480
2	23.3	803	39	492
2.5	20.4	758	42	517
3	16.6	715	48	541
4	8.8	634	66	594
5	1.1	562	79	652
6	- 5.6	495	72	715
7	-11.0	436	56	803
8	-17.1	382	45	895
9	-24.2	333	45	980
10	-31.6	290	-	1110
11	-39.4	251	-	1250
12	-47.0	217	-	1390
13	- 54.7	186	-	1560
14	-61.5	158	-	1780
15	-66.4	134	-	2060
16	-69.8	114	-	2460
17	-70.0	96	-	2830
		SANTA MARIA, CALIFORNIA		
20	-58.1	58	-	4960

Data for Molar Volume-Altitude Graph

Altitude, ft.	Molar Volume, $ft.^3$	Altitude, ft.	Molar Volume, $ft.^3$
5,000	420	50,000	2200
10,000	490	55,000	2850
15,000	590	60,000	3700
20,000	680	65,000	4900
25,000	820	70,000	6200
30,000	980	75,000	7800
35,000	1230	80,000	10,000
40,000	1410	85,000	12,600
45,000	1750	90,000	15,900
		95,000	20,200
		100,000	25,600

This data assumes a constant temperature (-60°C) above 65,000 ft., and below that altitude is based on representative pressures and temperatures taken from Washington, Albuquerque, Pittsburgh and Lakehurst soundings.

Individual variations from season to season, and from station to station may be noted in the graphs at the left of Figures 19 and 20. These variations are at most about 10%.

Remuneracion

La materia ha volado con este globo desde la New York University para hacer investigaciones meteorologicas. Se desea que esta materia se vuelva para estudiarle nuevamente.

Con este motivo, se dara una remuneracion de _________ dolares norteamericanos y una suma proporcional para devolver todos los aparatos en buen estado. Para recibir instrucciones de embarque, comuniquense con la persona siguiente por telegrafo, gastos pagados por el recipiente, refiriendo al numero del globo _________.

CUIDADO!
PELIGRO DE FLAMA. HAY KEROSEN EN EL TANQUE.

C.S. Schneider
Research Division
New York University
University Heights
Bronx 53, N. Y.

NOTICE

This is special weather equipment sent aloft on research by New York University. It is important that the equipment be recovered. The finder is requested to protect the equipment from damage or theft, and to telegraph collect to: Mr. C. S. Schneider, New York University, 181st St. & University Heights, West Hall, New York City, U.S.A. Phone: LUdlow 4-0700, Extension 63 or 27. REFER TO FLIGHT #

A dollar ($) reward and reasonable reimbursement for recovery expenses will be paid if the above instructions are followed before September 1948.

KEEP AWAY FROM FIRE. THERE IS KEROSENE IN THE TANK.

CUESTIONARIO

Tenga la bondad de contestar lo siguiente y enviarlonos para que podamos mandarle a Ud. la remuneracion.

1. En que fecha y a que hora se descubrio el globo?

2. Donde se descubrio? Indique la distancia y direccion aproximada del pueblo mas cercano que se encuentra en el mapa del sitio de descubrimiento.

3. Se observo bajar? Cuando?

4. Se bajo despacio o se cayo rapidamente?

QUESTIONNAIRE

Please answer this and send to us so that we may pay you the reward.

1. On what date and at what hour was the balloon discovered?

2. Where was it discovered? (Approximate distance and direction from nearest town on map?)

3. Was it observed descending? If so, when?

4. Did it float down slowly or fall rapidly?

WEIGHT SHEET

Flight No. ____________ Date ____________

Time ____________

Balloon Manufacturer ____________

Number ____________ Quantity ____________

Burnout Patch and Wires. . . . ____________

Shrouds . . . . ____________

Total Balloon Weight . . . . ____________

Launching Remnant . . . . . ____________

1st Unit. Serial No. ____________

description ____________ ____________

Line length ____________ ____________

2nd Unit. Serial No. ____________

description ____________ ____________

Line length ____________ ____________

3d Unit Serial No. ____________

description ____________ ____________

Line length ____________ ____________

4th Unit Serial No. ____________

description ____________ ____________

Line length ____________ ____________

Banner description ____________ ____________

Ballast assembly - description ____________ ____________

____

____

____

Ballast . . . . ____________

Total Equipment Weight. . . . . ____________

Gross Load . . . . ____________

RATE OF RISE AND MAXIMUM ALTITUDE COMPUTATIONS

Flight No. ______________________ Date ______________________

Time ______________________

BALLOON INFLATION

Desired Rate of Rise . . . . ________________ ft./min.

Gross Load . . . ____________

Assumed Gross Lift (Gross Load + 10%) G ________________

$G^{2/3}$ ________________

Free Lift - $F = (\frac{V}{412})^2 G^{2/3}$ . . . ________________

Equipment Weight. . . . . ________________

Desired Balloon Inflation = Free Lift + Equipment Total ______________ grams

Allowance for Leakage @ ________ gm/hr, ______ hrs. waiting ______________ "

Actual Balloon Inflation . . . . ______________ "

MAXIMUM ALTITUDE

Balloon Volume. . . . . . ________________ cu. ft.

Gas Lift/mol . . . . . . Helium 11.1 kg/mol; Hydrogen 12.0 kg/mol

Molar Volume = $\frac{\text{Balloon volume x gas lift/mol}}{\text{gross load}}$

________________ cu. ft.

Maximum Altitude . . . . . ________________ ft. m.s.l.

Altitude Sensitivity . . . . ________________ ft./kg.

BALLAST COMPUTATIONS

Flight No. ________________ Date ________________

Time ________________

Surface Balloon Diffusion (measured) (estimated) . . . ________________ gms/hr

Percent Inflation. . . . . . . ________________

Full Balloon Diffusion: Surface Diffusion x $\left(\frac{1}{\%\ \text{inflation}}\right)^{2/3}$

____

Ballast Leak (120% Full Balloon Diffusion). . ________________

Automatic Ballast Valve Calibration

____

Estimated Ballast Duration. . . . . ________________

New York University
Research Division
Balloon Project

Supplementary Information for Flight No. ________

Release: Site ______________ date ____________ time ____________

Encoded Sounding Data:

Encoded Upper Winds

Release Weather

In-Flight Hourly Weather

Train Sketch in Folder ______________ Films Sent Out ______________

List Flight Records in Folder:

Remarks

Checked by ____________________

Transmitter Performance for Flight No. ______________________________.

Release: Date __________ Time ________________ Site ______________.

Transmitter Type and Serial No. ______________________________________.
Batteries: ' Type and Number ____.

Open Circuit Voltages:

Voltages Under Load:

Reception at Station #1

Reception at Station #2

Reception at Station #3

Critique

REFERENCES

1. Meisinger, C. L. "Constant Elevation Free-balloon Flights from Fort Omaha," Monthly Weather Review, Vol. 47, pp. 535-538, 1919.

2. "Progress in Developing a Constant-Level Balloon", Report by Dewey and Almy Chemical Company, Cambridge, Massachusetts, June 15, 1944.

3. "Analysis of Japanese Weather Service", Air Weather Service Technical Report 45-1, Langley Field, Virginia, May, 1946,

4. Clarke, E.T., Korff, S.A., "The Radiosonde: The Stratosphere Laboratory", Journal of the Franklin Institute, Vol. 232, No. 3, September, and No. 4, October, 1941.

5. Middleton, W.G.K., Meteorological Instruments, Toronto, Canada, 1941, p. 46.

6. "Aerological Observations", Monthly Weather Review, Vol. 71, pp. 202-3, 1943.

7. Brombacher, W. G., "Altitude-Pressure Tables Based on the United States Standard Atmosphere", Report No. 538, National Advisory Committee for Aeronautics, Washington, D. C. September, 1935.

8. Timoshenko, MacCullough, Elements of Strength of Materials, Vol. 1, p. 51.

9. Lange, K. O., Unpublished Report, Lexington, Kentucky, 1947.

10. Warner, E. P., Aerostatics, The Roland Press Co., New York, 1926.

11. "The National Geographic Society - "U.S. Army Air Corps Stratosphere Flight of 1934 in the Balloon 'Explorer'", Contributed Technical Papers of the National Geographic Society, Washington, 1935.

12. The National Geographic Society - "U.S. Army Air Corps Stratosphere Flight in the Balloon 'Explorer II'", Contributed Technical Papers of the National Geographic Society, Washington, 1936.

13. Lugeon, Jean, "Le Poste Aerologique de la Station Centrale de Meteorologie a Payerne et les nouvelles methodes suisses de radiosondage", Extrait des Annales de la Station Centrale Suisse de Meteorologie, 1941; Zurich, 1942

14. Lugeon, Jean, "Quelques Innovations aux Methodes Suisses de Radiosondage," Tirage a part des Annales de la Station Centrale Suisse de Meteorologie, 1942, Zurich, 1943.

15. Upson, R., Chandler, C. Free and Captive Balloons, The Roland Press Co., New York 1926.

16. Prandtl, L., Tietjens, O.G., Fundamentals of Hydro-and Aeromechanics, the Maple Press Co., York, Pa.

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CONTROLLED-ALTITUDE FREE BALLOONS

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(Manuscript received 4 December 1947)

ABSTRACT

The results of an experimental program to develop balloons with associated control devices, which will float at constant pressure in the atmosphere, are given.

Newly developed plastic balloons and automatic ballast equipment are described. Examples of successful controlled-altitude flights are shown, together with a preliminary analysis of their trajectories.

The constant-level balloon may provide data not obtainable from an ordinary pilot-balloon network. Future possibilities and plans for its use are indicated.

1. Purpose

Drift bottles have been used for many years in the study of ocean currents and have provided interesting data. In meteorology, no corresponding device has been available. It is evident, however, that a balloon which is free to move with the air currents, and yet whose altitude can be controlled, has many important applications in meteorology, as well as in other fields, where it may be desired to keep instruments at altitude for considerable lengths of time. An example is in the investigation of cosmic rays; here, clusters of ordinary extensible meteorological balloons have been used, but the constancy of altitude obtained is not sufficient for many meteorological applications. The purpose of the present investigation[1] was to develop a balloon with a control system which would fly at a predetermined constant level for periods of many hours. Such a balloon has wider application than the ocean drift bottle, because, whereas the latter is limited to surface (or near surface) currents, controlled free balloons may be set to drift at any pressure elevation desired, or along other thermodynamically defined surfaces, as long as the element defining the surface changes in a monotone fashion in the vertical.

In addition to the uses for maintaining instruments at high elevations, there are numerous potential applications of these balloons. Direct measurements of air trajectories and of lateral diffusion become possible. The balloons may also be used as vehicles to convey and drop radiosondes over ocean areas. One problem in this application is to obtain an absolute altitude tie-in point, as it will be difficult to identify the point at which the radiosonde reaches the sea surface.

2. Earlier attempts

There have been numerous attempts for various purposes to get a balloon or group of balloons to stay at a fairly constant altitude. Meisinger was interested in the meteorological aspects of this, using a manned balloon. In the investigation of cosmic rays, as for example, by Clarke and Korff (1941), clusters of ordinary meteorological balloons, 350-gram or 700-gram size, numbering anywhere from twenty to nearly seventy, were utilized. No altitude-control devices were used; the balloons were merely given different amounts of inflation. Thus the whole train ascended to an altitude where certain of the more highly inflated balloons burst until the remainder just balanced the load; thereafter, the assembly descended slowly due to loss of lift by the diffusion of gas. The only provision for having the system regain altitude if it descended too low was by arranging the launching before dawn, so that after the bursting of the first balloon and the subsequent descent, superheating of the balloons by the rising sun would cause the whole assembly to rise again, thereby increasing the duration of the flight. The system does not have sufficient control for many purposes.

The much-publicized use of balloons by the Japanese in the last war represents an attempt which must be considered highly suecessful from the point of view of the length of time which the balloons stayed in the air. Here the objective was not to obtain any critical altitude control, but rather to insure that the balloons remained floating. The Japanese nonextensible balloons were of two types. One type was of heavy paper, coated to minimize diffusion, of spherical shape, about 25 to 30 ft in diameter, and containing about 19,000 cubic feet of gas. A solid-ballast control system was utilized and gas was valved at a low internal pressure (about two inches of water) to prevent the balloons from rupturing due to the increase of the internal pressure by altitude fluctuations or radiation changes. Such a valve tends to conserve the lifting gas but acts as a safety device to prevent damage of the envelope due to too great an internal pressure.

The solid-ballast system was complex; approximately 900 pounds of sand was used on each balloon, distributed in thirty-six bags. The dropping of ballast

[1] Sponsored by, and in cooperation with the Watson Laboratories of the Air Materiel Command.

was controlled by a baroswitch arrangement which dropped a bag by igniting a fuse when the altitude fell below any one of four different levels between 25,000 and 5000 ft. In addition, a delay mechanism consisting of a two-minute fuse was arranged between successive switches so that after ballast was dropped, two minutes would be allowed for the balloon to regain its altitude; if it did not regain in this time another bag of ballast would be dropped. The system was inefficient because if any one of the thirty-six fuse arrangements failed, no more ballast was dropped.

The second type of Japanese balloon was similar, in general, but slightly larger; it was made of oiled silk and therefore would stand a greater internal pressure (approximately six inches of water). The higher the internal pressure that the balloon can stand, the less gas need be valved under conditions of superheating or altitude fluctuations. The Japanese released many balloons of these types from their islands and estimated five to seven per cent of those released reached the west coast of this country. The balloons floated between the surface and 30,000 ft above sea level; those which reached the west coast must have remained aloft from four to ten days. While the altitude maintained was not constant, these balloons were highly successful for the time they remained in the air.

An attempt in this country was made in 1943 by the Dewey and Almy Company, to obtain constant-level balloons which would float at altitudes up to 15,000 ft. An ordinary 350-gram meteorological balloon was used but its volume was controlled by a nonextensible shroud around it. With this method a flight at about 5000 ft was obtained at fairly constant altitude for about an hour and a half.

3. Design of controlled-altitude balloons

As a result of the Japanese and other experiments, the use of a nonextensible envelope for the balloons was indicated. If a perfectly nonextensible balloon could be built with no diffusion through the walls, and which could withstand a high internal pressure, it would automatically stay at a constant density where the buoyancy of the full balloon equaled the load. In practice, control devices are needed to offset the leakage and diffusion of gas, to compensate for vertical currents in the atmosphere, to correct for the motion of the balloon due to diurnal changes of the balloon's temperature, and to compensate for the valving of gas which is necessary to prevent rupture of the envelope. It was decided to use a plastic as the balloon fabric, as some modern plastics are quite transparent to radiation, strong, easily fabricated, and relatively inexpensive as compared with coated fabrics.

A. Choice of plastics.—In the selection of a plastic material of which to make the balloons, the desirable properties are: (a) low brittle temperature, (b) low permeability, (c) high tensile strength, (d) high tear resistance, (e) chemical stability, (f) high radiation transmission or reflection. *Polyethylene* soon recommended itself for use, with its brittle temperature of below −80F. It is apparently unaffected by ultraviolet and ozone. The permeability through one mil of thickness and one square meter of area for 24 hours is ten liters for hydrogen and seven liters for helium, at normal atmospheric temperature and pressure.

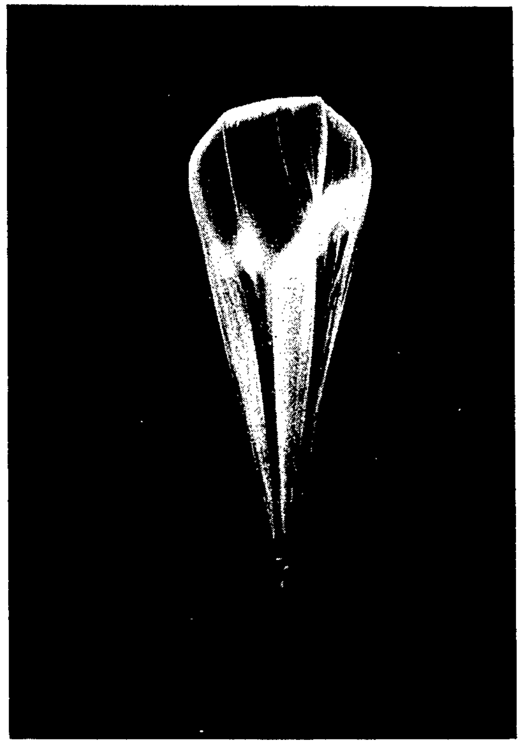

FIG. 1. Polyethylene balloon, 20-ft diameter.

Polyethylene is also relatively easy to fabricate. It has an ultimate tensile strength of 1,900 pounds per square inch at 25C, which, in a 15-ft balloon made out of four-mil fabric, represents a working pressure of about 2.3 inches of water. The tensile strength at the temperatures at which the balloon flies at high altitude may be more than three times the value quoted above.

Fig. 1 shows a polyethylene balloon[2] flown successfully in Flight 26 described below. Another film investigated is *Saran*, which has ten times the tensile strength of polyethylene—three times the strength across the seams. Saran has a higher transparency and one-thirtieth the permeability of polyethylene. The effective brittle temperature of Saran for this work is not known reliably.

B. Ballast valve.—The altitude control is an automatic ballast-dropping device[3] consisting essentially of

[2] Made by General Mills, Inc.
[3] Made by Kollsman Instrument Division of Square D Company.

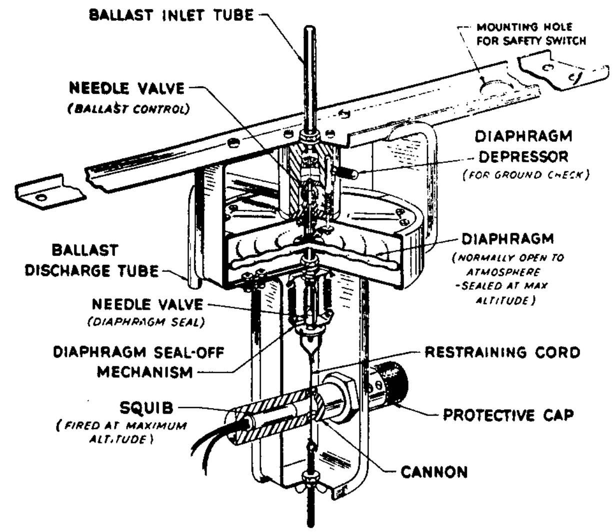

FIG. 2. Automatic ballast valve.

a diaphragm-operated needle valve which jettisons liquid ballast whenever the balloon is below the altitude at which the control is actuated. This is shown in fig. 2. The ballast reservoir (fig. 3), in general, can hold 15 kilograms of the liquid ballast—usually compass fluid, a highly refined kerosene-type petroleum product. When the atmospheric pressure outside the diaphragm is 5 millibars above the internal pressure, 160 grams of ballast per minute flow under a one-foot head. When the automatic ballast valve is wide open, which is after 6.5 millibars increase over the internal pressure, 300 grams per minute flow. These values may be compared with a diffusion loss of lift of the order of magnitude of 10 grams per hour from the thicker 15-ft balloon described below. Quite positive altitude control can be obtained.

Efforts are made to cause the static rate of leakage, *i.e.*, the leakage which proceeds when the automatic ballast valve is closed, to exceed slightly the rate of loss of lift due to the diffusion of the lifting gas from the balloon. To facilitate setting the fixed leak, a manually operated ballast valve, consisting of a leak adjustable by means of a fine needle valve, is added to the ballast-release assembly.[4]

C. Minimum pressure switch.—Obviously, the automatic ballast valve must not be in operation while the balloon is rising, as this would be a waste of ballast. Therefore the automatically operated needle valve is closed until the balloon reaches altitude. This is accomplished by having the loaded diaphragm of the altitude control open to the atmosphere until the balloon descends from a minimum pressure. At this time, an electrical contact is made and a squib[5] cuts a restraining cord and allows a needle valve to seal off the diaphragm from any further access to the air (fig. 2). The capsule then contains a volume of air which has been trapped at the existing pressure and temperature, at the time of operation of the sealing switch. Thereafter the aneroid will withdraw the ballast-control needle valve when the ambient pressure increases to the point where the entrapped air is compressed below this volume.

Fig. 4 shows the minimum pressure switch which makes the electrical contact at the time of seal-off. It consists of a trapped volume of air that is allowed to escape through a mercury pool as long as the outside pressure is decreasing. As soon as the exterior pressure increases once more, however, mercury is drawn into the tube, making the seal-off contact between two electrodes.

4. Height determination

Up to the present time, the standard radiosonde has been used in order to determine the altitude at which the balloon is flying. This permits a regular radiosonde ascent to be obtained during the period that the balloon is rising. Thereafter, as the balloon remains at approximately the same altitude, it becomes somewhat difficult to identify the radiosonde contact, but utilizing both the temperature and pressure indication, this is possible. A special radiosonde modulator of the Olland type has been designed (fig. 5). The pressure

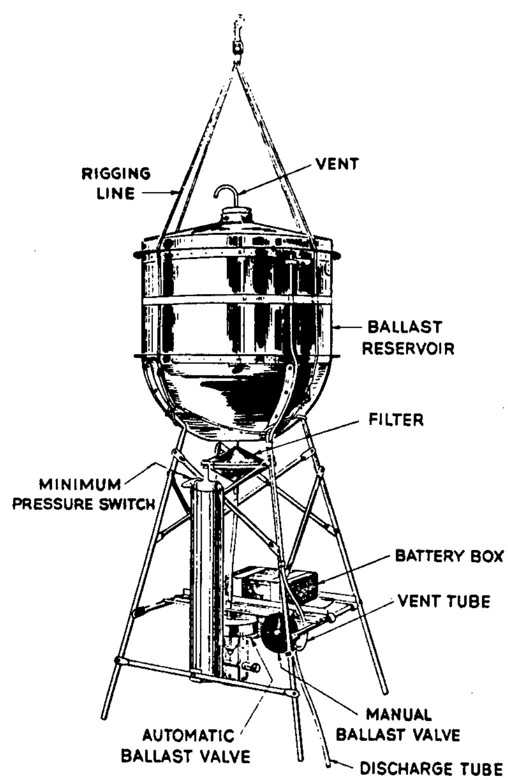

FIG. 3. Ballast-release assembly.

[4] Since this manuscript was written, the procedure has been simplified. Only a simple fixed leak is used for daytime flights. The automatic ballast valve is used alone for flights through sunset or sunrise.

[5] A small electrically detonated charge.

capsule and linkage is of conventional design but in place of the commutator bar, a motor driven helix is employed. This system permits the determination of

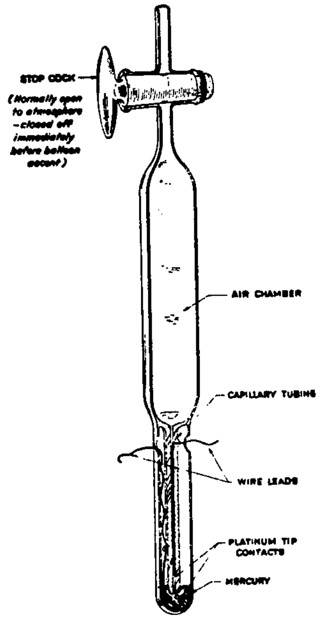

FIG. 4. Minimum pressure switch (mercurial).

pressure data without knowledge of the history of contact sequence or of the ascent or descent of the balloon, as is required in the conventional radiosonde.

5. Tracking of the balloon

The balloons that have been flown by the writers usually have been tracked by theodolites. Airplanes have also been used, to extend the observations. These two methods require the balloon to be visible and not obscured by cloud cover. When available, ground radar has been used in tracking the balloons, with good results.

A series of SCR 658 radio direction-finders is also used, arranged in a net along the expected trajectory of the balloon. In addition, aircraft equipped with inverted search radar have been employed to extend the tracking net.

6. Flight results

While the characteristics of various plastics were being investigated, four preliminary flights were made with clusters of ordinary meteorological balloons, from 16 to 26 in number, to which two to four towing balloons were attached. The towing balloons were cut free by a baroswitch at a predetermined altitude. The remainder of the balloons were inflated so that they exactly balanced the load hung from the cluster. To offset diffusion, sand was dropped from an arrangement of tubes, 9 to 16 in number, each containing about 200 to 1500 grams of sand ballast. This ballast was dropped by a baroswitch mechanism on descent only. Some of these flights were relatively successful as a beginning method but the dropping of discrete quantities of sand caused too great fluctuation of altitude and therefore was abandoned later. The first successful flight stayed at 51,000 ft, plus or minus 100 ft, for 38 minutes; another remained between 30,000 and 40,000 ft for 147 minutes. The latter shows the same characteristic time-altitude curve as the cosmic-ray clusters, although its altitude control is superior. It is not believed that much improved altitude control can be obtained, utilizing ordinary meteorological balloons. Flight termination was usually due to deterioration of the balloon caused by the sun.

In the first flight utilizing plastic balloons, a cluster of ten seven-foot diameter balloons[6] was used. The load on the cluster was 16.5 kilograms. An altitude control was used. Unfortunately, the maximum altitude reached was not as high as the predetermined altitude which was selected to seal the diaphragm of the automatic ballast valve. As a result, the cluster rose to ceiling and stayed at this altitude for a short while. Diffusion and leakage of helium produced a loss of lift at the rate of 125 feet per minute.

The next flight was made with a single polyethylene balloon, 15 ft in diameter. To insure sealing-off, the ballast-release diaphragm was set to operate at an altitude of 12,000 ft, considerably below the calculated ceiling of the balloon. After a dawn release the balloon continued to ascend to 15,100 ft where it leveled off, then slowly descended to 9000 ft due to diffusion losses. At this altitude the ballast release began to operate and thereafter the balloon maintained its altitude within ± 1300 ft for a period of $4\frac{1}{2}$ hours before the radio signal was lost. However, in the first two hours of this period, before the convection currents

[6] Made by General Mills, Inc.

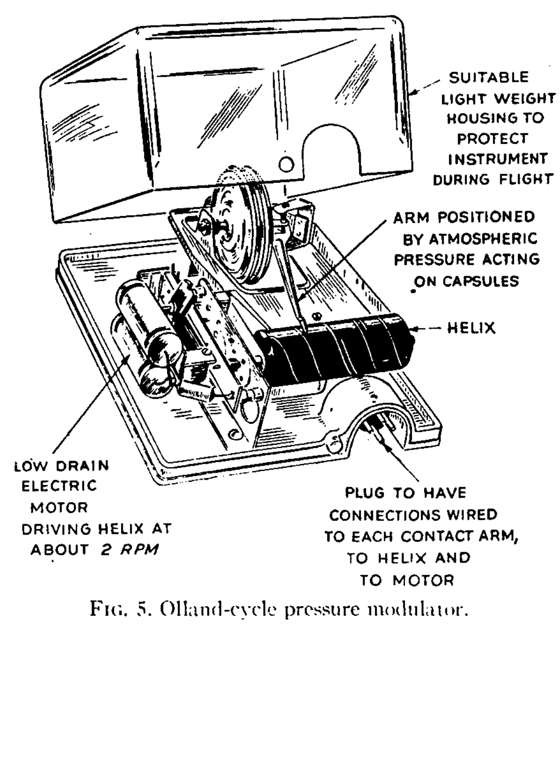

FIG. 5. Olland-cycle pressure modulator.

from the desert set in, the balloon maintained an altitude of 9200 ± 150 ft.

An explanation as to why the ballast release functioned at 9000 ft, although it was set to operate at 12,000 ft, is plain from the following data. The air in the diaphragm was sealed off on the dawn ascent at 12,000 ft, where the pressure was 657 mb and the temperature 9C. However, by the time the balloon passed through this level during the slow descent, the instrument temperature was 19C. This means that the pressure of the air trapped inside the diaphragm was higher than it was at time of seal-off.

For the ballast valve to function, the balloon had to descend to a pressure which would be greater by about 3 mb than the pressure of the trapped air at its now higher temperature. Of course, there was little ventilation past the instrument, and therefore the instrument temperature was about 25C above the ambient temperature after the sun had risen.

The automatic ballast valve operates when the volume inside the sealed diaphragm becomes slightly less than the volume at seal-off. Denoting the altitude at which it can operate by the subscript h, the pressure divided by the temperature at this altitude will equal the pressure at the seal-off altitude divided by the trapped-air temperature at the time of seal-off; in this case

$$p_s = 657 \text{ mb}$$
$$T_s = 9\text{C} = 282\text{A}$$
$$T_h = 39\text{C} = 312\text{A},$$

where the subscript s refers to seal-off. Thus the pressure at altitude h is given by

$$p_h = p_s T_h / T_s = 727 \text{ mb}.$$

This pressure, at which ballast release will begin, corresponds to an altitude of 9000 ft, which is the observed altitude maintained by the balloon for nearly $4\frac{1}{2}$ hours, until the radiosonde tracking signal was lost. The theodolite lost the balloon in clouds earlier and the airplane observer never succeeded in seeing it, so the balloon may have remained for a considerably longer period at this altitude. Eleven hours after beginning the ascent, the balloon was reported to have been seen over Albuquerque, New Mexico, and about 26 hours later a report was made from Pueblo, Colorado, which seemed to indicate that the balloon was still in the air at that time. The meteorological situation and wind data for that area at the time of flight support the contention that the latter observations were of the same balloon.

The next flight consisted of an assembly of various balloons, as follows:

One 15-ft diameter 0.008-inch polyethylene balloon,
Six 7-ft diameter General Mills 0.001-inch polythene balloons,
Two 350-gm meteorological balloons for stadia measurements.

The single balloon had a measured diffusion loss of lift of 4 grams per hour. The General Mills balloons were observed to lose lift at the rate of about 100 grams per hour per balloon.

Three of the 7-ft balloons were inverted and deflated shortly after launching, due to differences in the rates of rise of the various balloons in the cluster. Therefore, the altitude reached was not high enough to effect seal-off. (It is for this reason that the minimum pressure switch was developed for use in later flights.)

Fig. 9 shows the elevation and plan views of the track of this flight. The train leveled off at 16,500 ft. The diffusion loss of lift of the remaining balloons was approximately 300 grams per hour. The ballast valve used had an unusually high rate of static leakage which had been measured before release and found to be 310 grams per hour. Thus fortuitously, the loss of lift was compensated by ballast leakage. This nearly

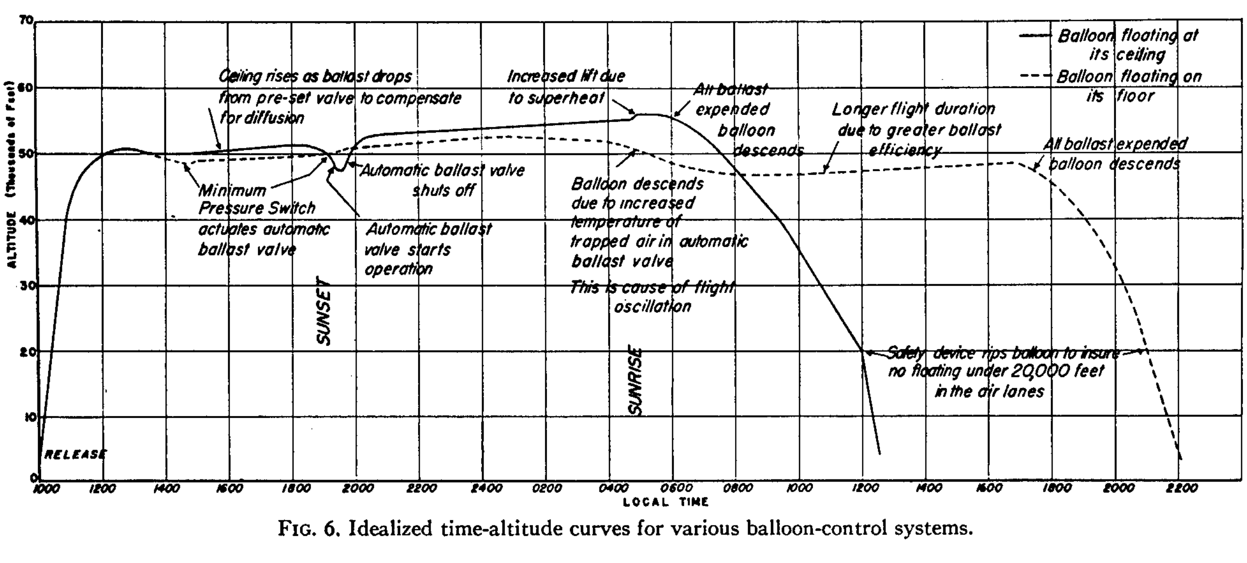

FIG. 6. Idealized time-altitude curves for various balloon-control systems.

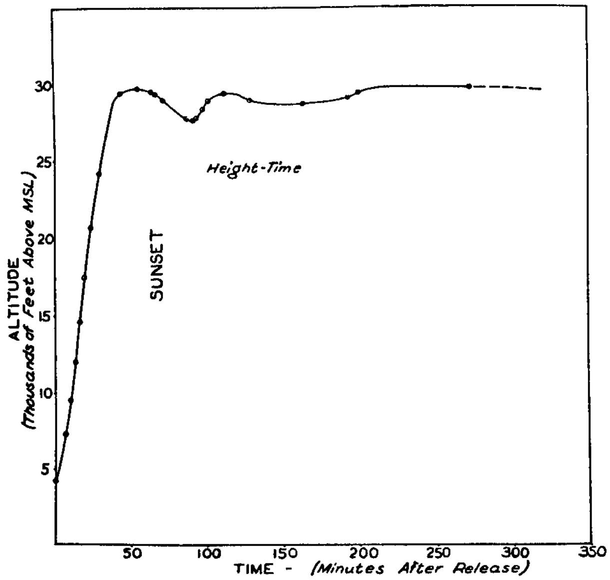

FIG. 7. Height-time curve of balloon Flight 17. Released at Alamogordo, New Mexico, on 9 September 1947 at 1647 MST (105th meridian). Recovered near Pratt, Kansas, 530 miles distant.

constant leakage held the balloon at 16,800 ± 700 ft for 7 hours. The duration of the flight was $9\frac{1}{4}$ hours. When the original 2700-gram ballast was expended, the balloon descended rapidly. Even had the automatic ballast valve been functioning, the constancy of altitude would have been the same. This seems to indicate that only a minimum of automatic control is needed, provided that diffusion losses are slightly overcompensated by a constant ballast leak.

Other flights also indicate the importance of a check valve in the balloon appendix to prevent dilution of the lifting gas with air. If this is not done, the altitude reached is far under the theoretical altitude determined by the displacement and gross load.

7. Control systems

Two systems of control are possible with the equipment as described. The balloon is controlled between an upper level (ceiling), where the full balloon buoyancy just equals the load, and a lower level (floor), below which the automatic ballast valve operates. Schematic curves for these two systems of control are shown in fig. 6.

In the first system of control the rate of static ballast leakage is greater than the diffusion loss of lift, and the balloon will stay at the ceiling. If it is displaced above the ceiling the buoyancy is insufficient to balance the load and it will descend again. Provided the rate of ballast discharge is greater than the rate of lift by loss of gas this ceiling will slowly rise by valving of gas, and as gas is lost by diffusion. The less the amount of gas the lower the pressure (higher ceiling) must be for the gas to fully distend the envelope. Unnecessary valving is undesirable and may, in part, be minimized by use of a restraining safety valve set in the appendix, which will allow some slight pressure to be carried in the balloon, preventing gas loss at the peaks of minor oscillations but still valving gas before the balloon ruptures due to too great an internal pressure.

In this system of control, the automatic valve is not sealed off until the balloon starts a descent due to cooling or other changes in lift, as when night falls. Upon descent the valve is activated and starts dropping ballast immediately; this continues until the balloon is no longer losing lift at a rate greater than the diffusion losses. The balloon will then rise above its former ceiling to a height determined by the weight of ballast dropped, and remain there as long as there is ballast to compensate for lift losses. Flight 17, reproduced in fig. 7, used a low-leakage balloon and is an actual case of ceiling control. It may be compared with the idealized time-altitude curves in fig. 6.

In the second system of control the static rate of leakage is less than the diffusion loss of lift. In this case the balloon will descend to the floor, where the automatic control operates and the balloon floats at an equilibrium altitude where the rate of ballast release exactly balances the rate of loss of lift. Floor control conserves ballast, since only that needed for altitude control is released. However, the altitude of the floor varies diurnally as the temperature of the entrapped air in the automatic ballast valve is affected by solar radiation. Two methods are being investigated to circumvent this undesirable feature. One is to

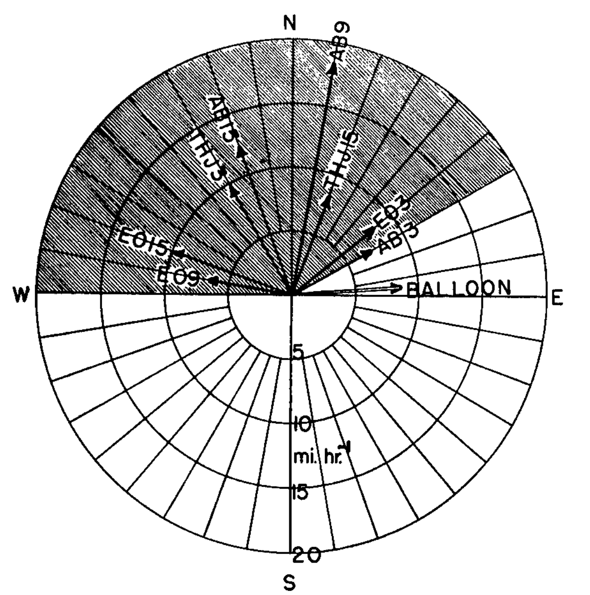

FIG. 8. Wind vectors at 16,000 feet for El Paso (EO), Albuquerque (AB), and Roswell (THJ), at 03^h, 09^h and 15^h (MST) on 7 July 1947, in connection with balloon Flight 11, mean motion of which is shown by the balloon vector. Cross-hatched sector contains all wind vectors at these three stations for the three observation hours and for the three levels, 14,000, 16,000, and 18,000 feet.

temperature-compensate the diaphragm, the other to insulate and shield the valve from radiation.

Using the ceiling-control system, flights of less than 24 hours not passing through sunset, may be held at ceiling by use of a nonextensible balloon and a simple fixed rate of leak to over-compensate diffusion losses. The constancy of level will be better the lower the diffusion and the lower, therefore, the rate of rise of the ceiling. The automatic control is needed for flights lasting through a period in which day changes to night.

8. Preliminary trajectory analysis of two constant-level balloon flights, 7 July 1947[7]

The most striking feature of the constant-level balloon flight (Flight 11, fig. 9) originating at Alamogordo Army Air Base at 05^h08^m MST[8] on 7 July 1947 is the disagreement between the actual trajectory and the trajectory that might have been estimated from routine upper-wind reports. In this connection the observations from the Weather Bureau stations at El Paso, Roswell, and Albuquerque have been examined, since the path of the balloon was contained within the triangle formed by these stations. Over El Paso, the wind direction at 16,000 ft (the approximate average altitude of the balloon during the greater part of the flight) was approximately SW at 03^h, ESE at 09^h, and ESE at 15^h. Over Roswell, the apparent average wind direction at 16,000 ft was S during this period. Over Albuquerque, which was considerably farther from the path of the balloon than the other two stations, the wind direction at 16,000 ft was variable between WSW and SSE during the interval from 03^h to 15^h. In contrast with these observations is the fact that the constant-level balloon floated in an essentially steady WSW current between 06^h and 09^h.

In fig. 8 the wind observations at 16,000 ft have been plotted for El Paso, Roswell, and Albuquerque for 03^h, 09^h, and 15^h. The wind directions at 14,000 ft, 16,000 ft, and 18,000 ft (only the intermediate level is shown in the figure) are all contained in the 150-degree sector between directions 90° and 240°; yet the mean motion of the balloon (approximately 265°) between 05^h48^m and 13^h11^m falls entirely outside this sector.

An indication that this local WSW current was of small depth is given by a special upper-wind observation made at White Sands at about 13^h. The observation in question recorded a wind direction of 250° at 16,000 ft, which is in excellent agreement with the first

[7] The authors are indebted to Prof. G. Emmons for contributing the major part of this section.

[8] Mountain Standard Time—105th meridian civil time. All further time references will be tacitly MST.

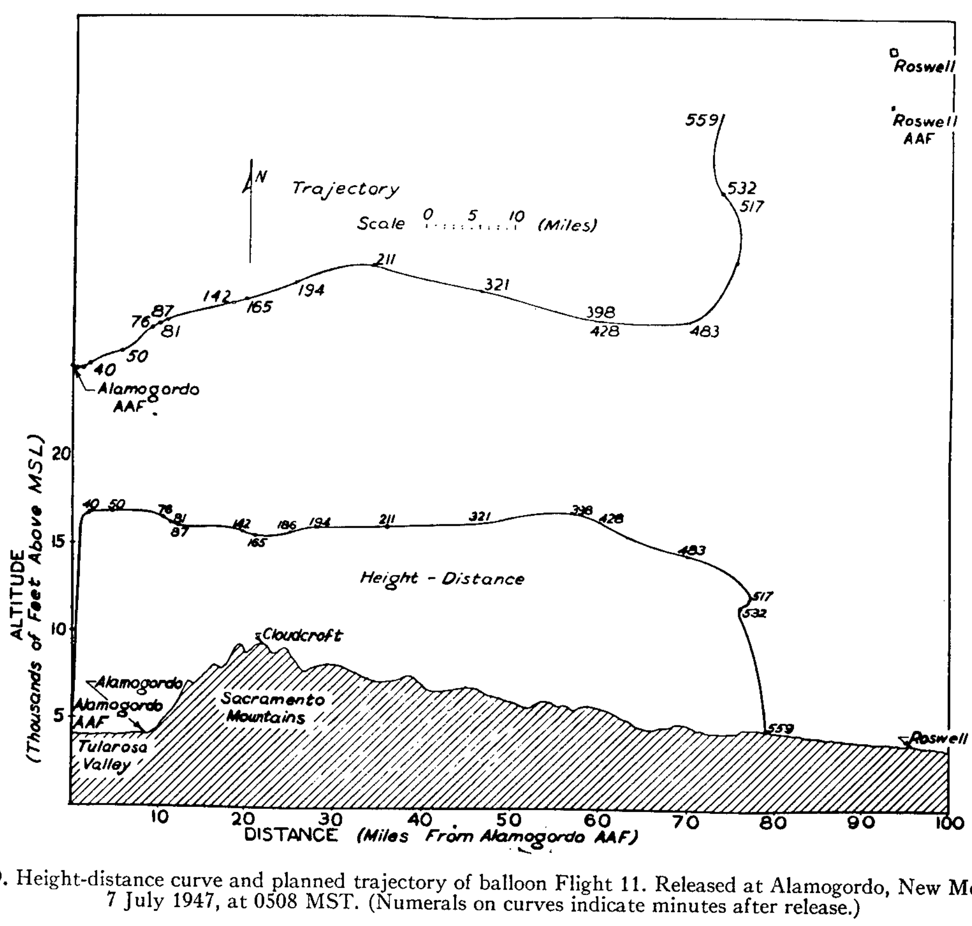

FIG. 9. Height-distance curve and planned trajectory of balloon Flight 11. Released at Alamogordo, New Mexico, 7 July 1947, at 0508 MST. (Numerals on curves indicate minutes after release.)

part of the trajectory of the constant-level balloon. The interesting fact about the White Sands observation is that *at all but one of the other reported altitudes* between the ground and 20,000 ft, the wind directions were from either the NE or SE quadrants.

The trajectory of the balloon curved slightly anticyclonically over the eastern slopes of the Sacramento Mountains. This characteristic is suggestive of the well-known deforming effect of a mountain range on an air current directed toward the axis of the range. In this case, however, the validity of invoking the aforementioned effect to explain the anticyclonic curvature, when the wind at levels below the mountain summits appears to have been blowing approximately parallel to the range, depends on assuming that the air currents parallel to the range themselves constitute a barrier deforming a higher current blowing in a different direction across the mountains. The sharp cyclonic bend that occurred after the balloon had come over relatively flat country occurred at the time that the balloon began its final descent and is due to the fact that the course of the balloon turned toward the north as a result of descent to levels where the wind had maintained a southerly direction throughout the day.

It is of interest to compare this flight with Flight 17 (fig. 10). It may be observed on fig. 10 that no deforming effect of the mountain barrier is apparent. This, however, is to be expected, as the altitude of the balloon above the mountain top is three times that of Flight 11, where this anticyclonic deformation of the trajectory was observed. The balloon was ultimately recovered from Croft, Kansas, a distance of 530 miles from the release point; on the basis of the observed wind speeds a 12-hour flight duration is estimated.

9. Conclusion

Within the coming year it is hoped that a number of meteorological investigations may be attempted, utilizing constant-level balloons. Release of three or more from a single point to float at the same level, release at a number of points to obtain a synoptic presentation of the trajectories in a chosen level, and the dropping of radiosondes from balloons are some of the operations to be attempted. Efforts will be made to simplify the arrangement so that a constant-level flight may be made in a routine fashion and at no greater cost than the ordinary radiosonde flight.

REFERENCE

Clarke, E. T., and S. A. Korff, 1941: The radiosonde: the stratosphere laboratory. *J. Franklin Inst.*, **232**, 217–355.

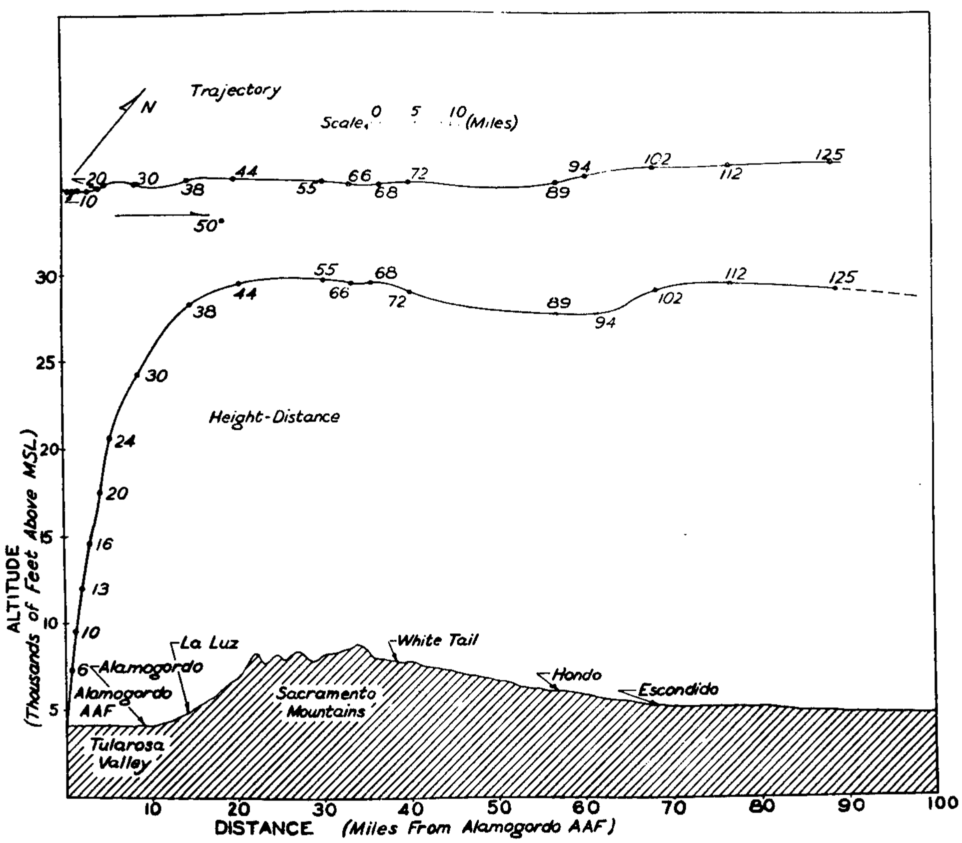

FIG. 10. Height-distance curve and planned trajectory of balloon Flight 17. Released at Alamogordo, New Mexico, 9 September 1947, at 1647 MST. First 125 minutes only are shown. (Numerals on curves indicate minutes after release.)